NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. IV. December, 1889. No. 2.

This Association, as a Body, is not responsible for statements or opinions of any of its members.

QUARTERLY MEETING.

YOUNG'S HOTEL, BOSTON, MASS., Dec. 11, 1889.

About eighty members and guests of the Association assembled on this date at Young's Hotel, in response to a call issued for the regular quarterly meeting. The names of those present, as far as the Secretary has been able to obtain them, are as follows: —

LIST OF MEMBERS ATTENDING MEETING OF DEC. 11, 1889.

F. A. Andrews, of Nashua, N. H.
S. M. Allen, of Malden, Mass.
C. H. Baldwin, of Boston, Mass.
W. H. Barney, of Milford, Mass.
Everett Barns, of Westerly, R. I.
J. E. Beals, of Middleboro', Mass.
W. R. Billings, of Taunton, Mass.
G. H. Bishop, of Middletown, Conn.
Dexter Brackett, of Boston, Mass.
J. H. Brown, of Charlestown, Mass.
E. W. Cate, of Newton, Mass.
G. F. Chace, of Taunton, Mass.
H. W. Conant, of Gardner, Mass.
R. C. P. Coggeshall, of New Bedford, Mass.
B. I. Cook, of Woonsocket, R. I.
F. H. Crandall, of Burlington, Vt.
Lucas Cushing, of Boston, Mass.
Edwin Darling, of Pawtucket, R. I.
A. B. Drake, of New Bedford, Mass.
H. L. Eaton, of Somerville, Mass.
G. E. Evans, of Lowell, Mass.
Desmond FitzGerald, of Boston, Mass.
F. F. Forbes, of Brookline, Mass.
J. R. Freeman, of Boston, Mass.
F. L. Fuller, of Boston, Mass.
A. S. Glover, of Newton, Mass.
J. A. Gould, of Newton, Mass.
E. H. Gowing, of Reading, Mass.
R. A. Hale, of Lawrence, Mass.
F. E. Hall, of Quincy, Mass.
J. L. Harrington, of Cambridge, Mass.
D. A. Harris, of New Britain, Conn.
J. C. Haskell, of Lynn, Mass.
W. M. Hawes, of Fall River, Mass.
Patrick Kieran, of Fall River, Mass.
G. A. Kimball, of Boston, Mass.
T. C. Lovell, of Fitchburg, Mass.
Hiram Nevons, of Cambridge, Mass.
J. H. Perkins, of Watertown, Mass.
G. J. Ries, of East Weymouth, Mass.
W. H. Richards, of New London, Conn.
W. W. Robertson, of Fall River, Mass.
Henry Rogers, of Salem, Mass.
J. H. Shedd, of Providence, R. I.
S. F. Smith, of Grafton, Mass.
G. A. Stacy, of Marlboro', Mass.
F. P. Stearns, of Boston, Mass.
M. M. Tidd, of Boston, Mass.
C. H. Truesdell, of North Grosvenordale, Conn.
G. P. Westcott, of Portland, Me.
W. P. Whittemore, of North Attleboro', Mass.
G. E. Winslow, of Waltham, Mass.
M. F. Wright, of Lowell, Mass.
E. R. Jones, of Boston, Mass.

And representatives from —

American Frost Meter Company.
H. R. Beecher Manufacturing Company, Lowell, Mass.
H. R. Worthington & Co.
Chadwick Lead Company.
Hersey Meter Company.
Holyoke Hydrant and Iron Company.
George Ross Company, of Troy, N. Y.
Union Water Meter Company.
Walworth Manufacturing Company.
Water Waste Prevention Company.
Whittier Machine Company.
And the "Engineering and Building Record."

For an hour or two before one o'clock the members assembled in the rooms provided for their use, and employed their time in social converse till lunch was announced, when they proceeded to the dining-room. At two o'clock, lunch being over and cigars lighted, President Brackett rapped to order, and called upon the Secretary, who presented the following-named list of applicants for membership in the Association: —

FOR ACTIVE RESIDENT MEMBERSHIP.

1. Elmer E. Farnham, Superintendent, Sharon, Mass.
2. Charles F. Parks, Civil Engineer, 89 State st., Boston, Mass.
3. William Wheeler, Civil Engineer, 89 State st., Boston, Mass.
4. John W. Ellis, Water Commissioner, Woonsocket, R. I.
5. John C. Haskell, Superintendent, Lynn, Mass.
6. W. H. Vaughn, Superintendent, Wellesley Hills, Mass.

FOR NON-RESIDENT ACTIVE MEMBERSHIP.

7. Edward M. Boggs, Hydraulic Engineer, San Bernardino, Cal.
8. William E. Davis, Superintendent, Sherburne, N. Y.
9. J. E. Denton, Prof. Experimental Mechanics, Stevens Institute, Hoboken, N. J.
10. E. P. Foster, Superintendent, Santa Anna Water Co., San Buenaventura, Ventura Co., Cal.
11. Harry G. Koch, Superintendent, Castle Creek Water Co., Aspen, Col.
12. Samuel B. Leach, Civil Engineer, North Tarrytown, N. Y.
13. C. H. Tompkins, Jr., Engineer and Manager, Idaho Mining and Irrigation Co., Boise City, Idaho Territory.

The Secretary stated that the applicants were all approved by the Executive Committee, and it was voted that the Secretary cast the ballot of the Association for the list as read. This having been done the President announced the gentlemen voted for as duly elected members of the Association.

The Secretary then announced the following changes in addresses of members: —

Melvin C. French, Superintendent, Box 165, So. Braintree, Mass.
Hiland C. Hitchcock, 99 Blossom st., Fitchburg, Mass.

There being no further business, President Brackett opened the discussion of the afternoon with the following remarks: —

The PRESIDENT. — *Gentlemen of the New England Water Works Association*, — The attendance here to-day assures me that you are still interested in the affairs of the Association, and also encourages me in the belief that you are all ready and willing to assist in making the meetings of the coming year as interesting and instructive as those of the past have been. For the honor which you have conferred upon me by placing me in my present position, I desire to thank the Association, and in fulfilling the duties of the office I shall assume that you all agree with the opinion of one of your former presidents, expressed in the statement that "it is water works and not oratory in which we are interested." One of the objects of the Association is the maintenance of a spirit of fraternity among the members by social intercourse and by the discussion of subjects relating to water supply; and in this spirit we should all be willing to do what we can to further the ends of the Association. The little things, the details which make up the bulk of our daily work, are often of great value, and the short papers which were presented during the last year, at one or two of the meetings, were of much interest. There was but a very small proportion of our members, however, who furnished us with those papers. It is proposed, at the next meeting in January, to continue this plan, and I wish to have as many as are willing volunteer to-day to present, at the next meeting, short papers, not to exceed five minutes in length, connected with the question of water supply. Who is willing to volunteer?

(Messrs. Richards, Coggeshall, Tidd, Nevons, Holden, Kimball, Eaton, Darling, Harrington, Winslow, Rogers, Hawes, Welch, and Hall either volunteered or were designated by the President.)

The PRESIDENT. — Since our annual meeting at Fall River there has been another gathering of the Association which was participated in by a number of those here present. I wish that all might have been there, and in order that those who were not with us may obtain some little idea of what occurred at our fall meeting I will now call on Vice-President Hawes, of Fall River, who will give you a report of our proceedings on that occasion. (Applause and laughter.)

FALL MEETING, SEPTEMBER, 1889.

Mr. HAWES. — It is a little too bad to disturb me just now, for I was 'most asleep. (Laughter.) I think considerable of that excursion. "I came, I saw, I conquered." (Laughter.) We went, we saw it, and we are mighty glad of it, — those who did go. (Laughter.) On the morning of the 29th of September — Saturday — we left Boston, and we had a very beautiful ride up to the Pemigewasset House, where we took dinner, as good as we could get (laughter); and then we went on to the Crawford House, where we arrived about half-past four or five o'clock, meeting with a very cordial reception, and being provided with a mighty good supper; and we were all ready for it, too. (Laughter.) The next

day was a beautiful day. The weather had been cold, and the highest mountain-tops were all covered with snow; and it was a strange and beautiful sight to most of us. We went up Mt. Willard, had a little snowballing, and a fine view. In the afternoon different parties wandered off to different places, and saw all there was to be seen. Some of the party started in the morning and went up to the summit of Mt. Washington and got "friz up." (Laughter.) The locomotive froze up while they were there, and they had to wait for it to be thawed out before they could come back (laughter); and they had a very cool time. We had a very pleasant gathering in the parlors of the Crawford House on Saturday and Sunday evenings, and a good sing.

On Monday morning about nine o'clock we left Crawford's and came down through the Notch to North Conway. The mountain scenery never looked better than it did then. Most of us who have been to the mountains have been in the summer, and have seen them in their dress of dark, cool green; but this day they were blazing in the brilliant glory of autumnal tints which illuminated the hill-sides, while the mountain summits were capped with the glistening white snow. We had impressed in our memories scenes which have made this tedious, bitter, cold, raw winter weather through which we are now passing seem bright to us. (Laughter.) We had our own train, our own private car, and our own water-boy, too. (Laughter.) I see you are inclined to laugh, but that is where the laugh comes in for those who were there. There were about sixty or seventy in the car, and we had a jolly good time. If there was anybody who went on that excursion who didn't have a good time, I would like to have him step outside and take it right out now; I will settle with him alone. (Laughter.) It was one of the pleasantest meetings that we ever had, one of the pleasantest of our field-day meetings, and it left a beautiful impression on the minds of both men and women, and I may add children, also. (Laughter.) I hope we shall be able to go again, and when we do go, you who couldn't go this time, hearing such favorable reports, I hope will be able to join us. I don't know that there is any more I can say, except that we all got home sober, as far as we could see (laughter), in a drenching rain. There were water works enough when we got home, you can bet on that. (Laughter and applause.)

At the conclusion of Mr. Hawes' remarks the President introduced Mr. Freeman, who read a paper entitled "Experiments and Practical Tables Relating to the Discharge of Fire Streams and the Loss of Pressure and Friction in Hose."

Mr. Freeman's paper was listened to with great interest, and at its conclusion was discussed by Messrs. Tidd, Jones, Brackett, Haskell, Shedd, Hawes, and Winslow.

[The paper and the accompanying discussion will appear in a future number of THE JOURNAL.]

At the conclusion of this discussion, upon motion of Mr. Hawes, the Association adjourned.

PAPERS READ AND DISCUSSED AT THE CONVENTION, HELD AT FALL RIVER, MASS., JUNE, 1889.

WATER-WORKS RECORDS.

BY

ALBERT S. GLOVER, Water Registrar, Newton, Mass.

It has often seemed strange to me that among the many subjects written upon and considered at our Water Association meetings, this of water-works records has never been discussed. With the exception of the able and valuable paper upon the desirability of a uniformity in the preparation and publication of water department reports, which was presented to our Association by Messrs. Billings and Coggeshall, in 1885, I know of no allusion to the matter. The importance of the question precludes, of course, the theory that it has been neglected through a lack of interest in it, and I think it can only be that the magnitude of the subject has acted as a discouragement to those attempting to write about it. I may possibly be inclined the more to this opinion from a slight study of the matter, since I was informed by our worthy secretary that I had been drafted to supply a paper upon this subject as a substitute for another expected from one of our members, who, fortunately for himself but unfortunately for you, has deserted us for the Engineer's Excursion abroad.

WATER-WORKS RECORDS.

This subject has a very wide range; it would include, of course, the records of systems of all kinds and descriptions; those deriving a supply from running streams, ponds, lakes, or wells; those sufficiently fortunate to be supplied by gravity, as well as those compelled by necessity to pump, by water or steam power, to a reservoir, stand-pipe, or directly into the distributing mains; those works owned by the public or by a private corporation, — in a word, the subject would include a record of the work of designing, constructing, operating, and maintaining every description of existing water-works systems.

To prepare a paper on a subject so important, to suggest the most feasible and practicable scheme for a system of records applicable to every water department in all its details, would be manifestly an undertaking of immense labor, and one involving a vast amount of time even by one competent to perform the task; moreover, the consideration of such a paper, assuming the work to have been done in such manner as to enable its author to present to you an exhaustive treatment of the matter, would be likely to profitably consume more time than you would probably have at your disposal at any one of our meetings. On this account it has seemed to me best to consider only the form and method of recording the daily work of such a system of water-supply as the majority of us

are daily associated with, leaving those larger, and, perhaps, more complex, for a future time and an abler advocate. I therefore take pleasure in approaching this subject by presenting for your consideration a short description of the form of records adopted by us at Newton as the result of about fourteen years' experience in water-works management. I do this, it is of course unnecessary for me to say, with no intention of claiming for it great superiority, or even especial merit, but simply with the feeling that in this manner the subject can best be introduced to you, and with the hope that as a result of the opportunity afforded you for comparing this system with your own, and by means of the discussion and criticism likely to follow, the entire matter of water-works records may receive the attention it deserves, and that we may be mutually benefited by giving to it at our future meetings more of the thought, study, and consideration to which its importance entitles it.

Before, however, touching upon our records, in order that you may as clearly as possible understand their application, it will be well for me, I think, to explain to you our situation at Newton, the character of our works and our form of government as it relates to the water department. As you are probably well aware, the city of Newton has a population of about twenty-three thousand people, distributed among ten different villages; it embraces in area 12,000 acres, and has 138 miles of streets. We obtain our principal water supply from an open gallery along the bank of the Charles river in the town of Needham, with a small auxiliary supply from driven wells on the Newton side of the river, near our pumping-station; the gallery is, speaking approximately, 1,600 feet long and 70 feet wide at the top, with sloping banks reducing the width to ten feet at the bottom; the water is conveyed from the gallery across the river through about 700 ft. of 24-in. pipe to a pump-well in the station, from which it is raised to our reservoir.

Our pumping plant consists of a 5,000,000-gallon compound duplex condensing-engine and a 1,000,000-gallon duplex high-pressure steam-pump, both of the Worthington make. Our reservoir is located on the easterly side of the city, about 3½ miles from the pumping-station; it has a capacity of 15,000,000 gallons, and its elevation affords an average pressure throughout the city of 60 pounds. We have about 87 miles of distributing mains, all of cast-iron, varying in diameter from 4 inches to 20 inches; on these mains are located 404 gates and 566 hydrants, and from them are supplied 4,000 service-pipes; on the service-pipes, for the measurement of water delivered, are placed 2,500 meters.

Conforming, I believe, to the universal custom in Massachusetts, the act of the Legislature authorizing the city to secure a water supply provided for the construction and management of the works under such rules and regulations, with certain limitations, as the city should see fit to adopt. The works were constructed by a commission wholly outside the city council, but upon their completion were turned over to the city, and managed for several years by a joint committee of the city government; for the last seven years, however, they have been in charge of a water board, which is composed of five members, three being selected from the citizens at large, and one each from the board of aldermen and the common council, the two branches of our government. The principal officers of the department, the registrar and superintendent, are appointed by the mayor, subject to confirmation by the board of aldermen, and hold office until death, resignation, or removal.

All the other employees of the department are appointed, and have their compensation established, by the water board. By an ordinance establishing the office of city engineer, he is *ex officio* the engineer of the board.

The action of the board is in a great measure controlled by the ordinance established by the city for the government of the department, but they have absolute control over all the department employees, except the appointment, removal, and establishment of compensation of the registrar, superintendent, and engineer. They have, consequently, authority, which they have exercised, to establish rules and regulations for the management of the works. Under these rules the registrar is the clerk and executive officer of the board, and to him daily all other officers of the department report, he being required to keep a careful and complete record of all the operations of the department, and to report thereon weekly to the water board.

In enumerating our system of records, we naturally begin with our source of supply. Although, as has been stated, we draw our water from a basin alongside the river, and although, as a matter of fact, we take very little water, if any, from the river, nevertheless, owing to a decision made in its wisdom by the Supreme Court of Massachusetts, we were obliged to pay to the mill-owners below us $25,000, for the privilege of taking from the river 1,500,000 gallons of water daily; it being therefore desirable to know approximately the quantity of water in the river, for the purpose of ascertaining how much damage would be caused the mill-owners if our authorized quantity should be exceeded, a daily record is made of the height of the water there. It is also desirable for us to know the height of the water in our filter basin, in order that we may know the supply we have in reserve. I have previously stated the dimensions of the basin, which has a capacity of between 5,000,000 and 6,000,000 gallons. Our pumping engineer, with very little trouble, attends to the reading of the river-gauge as well as that of the basin, and telephones the readings to the registrar's office, where they are recorded. A gauge, showing the height of the water in the reservoir, is taken twice a day, and also telephoned and recorded in a similar way. This latter, of course, gives us the quantity of water in reserve in the reservoir, and also shows, in connection with our pumping record, the daily consumption. An improvement on this system of reservoir-records is undoubtedly an automatic recording-gauge, such as has been the product of the genius of one of our fellow-members, and which not only keeps a continuous record of the elevation of the water in the reservoir, but automatically registers the elevation wherever required, regardless of its distance from the reservoir.

PUMPING-STATION RECORDS.

The importance of a complete record of work done at the pumping-station of a water department needs no emphasis at my hands to those of our Association, certainly, who are obliged to pump the water they use; only by such a record and a careful and constant study of it we can obtain the best results from our service.

The form adopted by us provides for a record of the time of start and finish of the run of the pumps; a record of the delivery of the pumps, including a reading of the counter, number of strokes, average per million gallons, length of strokes, and gallons pumped during run; a record of the water levels, including height of

pump-well, height of delivery, suction lift, static and dynamic head; a reading of the steam, vacuum, and water gauges; a record of the temperature of the atmosphere, engine-room, boiler-room, pump-well, feed-water, and air-pump delivery; a record of the water evaporated in the boilers; a record of the fuel used, keeping separately the quantity of coal used for raising steam and banking fires, for heating the building and for pumping; a record of the weight of ashes and clinkers remaining, and the duty record of the engine.

Under the rules of our board the pumping engineer telephones to the registrar at the close of each day's pumping the quantity of water pumped and the amount of coal used; he is also required to make weekly returns of a transcript of the record kept as hereinbefore described, which is recorded in the registrar's office.

DISTRIBUTION RECORD.

As I have before stated, our mains are all of cast-iron; they are made from specifications prepared by our engineer, with thicknesses computed by the Shedd formula, and are made with the Providence Bell. After they are cast they are inspected at the foundry, and a sworn statement of said inspection is forwarded to us, with the record of each individual pipe; on their receipt from the foundry they undergo a careful hammer inspection before acceptance; having successfully passed this inspection, they are placed in stock and charged to our stock clerk; it is his duty to know at all times how much pipe, as well as all other material, we may have on hand, and all pipe delivered by him is charged to the foreman taking it, who in turn reports the particular work in which it has been used, and to the expense of which it then becomes charged.

Applicants for extensions are required to file with the registrar a petition therefor setting forth that they own the premises for which the water is asked, and that they will take the water as soon as the main is laid, and conform to all the rules and regulations of the department; the superintendent then makes an estimate of the expense of the proposed extension, which is filed with the registrar, and upon which is based a guaranty that the petitioner is required to sign before further steps are taken in the matter; this guaranty provides for an assured income from the extension of 5 per cent. per annum of the cost of making it, exclusive of any receipts to the department from water sold to the city from hydrants, watering-troughs, etc., that may be placed upon the main in question. Before making the guaranty, there is deducted from the estimate the portion, if any, providing for the erection of hydrants, the city itself assuming this part of the expense.

The minimum time for which a guaranty is accepted is five years, and the requirement is often longer.

On an average there are always in force guaranties on 200 separate extensions of mains, and as these are made for varying terms, and begin and expire on all dates during the year, for properly keeping the accounts a book, provided with an index, and with the following headings, is necessary: Name of street; ward; date of laying main; length of term; amount of guaranty; and columns showing by years the amounts assessed, with the dates of payments.

Besides the guaranty, if the extension is requested for a street not accepted by the city, in other words, a private way, the petitioner is required to secure and

file with the registrar an agreement, signed by all owners abutting on the line of the proposed extension, that the city shall have the right to lay and maintain perpetually its pipe in said way. These papers being signed, they are laid, together with the petition, before the water board, and if the matter is favorably considered the extension is ordered laid. Extensions of pipe, as well as other out-of-door work generally, are made under the personal direction of the superintendent.

The board having acted favorably upon a petition, the superintendent is notified, and the order is placed on file, to be executed in its turn. The engineer is also notified, and establishes line and grade for the proposed extension. The work being undertaken, accurate record is kept, in the manner before outlined, of the stock of all description used therein, with an account of the labor performed; these returns are made to the registrar weekly, and from them the cost of the extensions are reported to the water board.

The engineer, besides giving line and grade, locates the pipes and makes a plan of the same for the registrar, on a scale of 600 feet to the inch. This plan also shows the position of all hydrants, gates, etc. Besides this plan, which is a general map of the city, the engineer provides sectional plans of the pipe-system, on a much larger scale, which are of especial value in looking up the location of service-pipes.

A description of the register used to record the details of extensions made is as follows: It is ruled in columns, providing for a note of date of laying of the main; the street and ward in which it is laid; the street connected with it; the size of connection main; cost of labor; cubic yards of rock excavation; the length in feet of size of pipe used; the cost of pipe; the number of pounds and cost of lead used; the number, kind, and cost of gates used; the number, kind, and cost of hydrants set; a description, weight, and cost of specials used; a description, with the amount of sundry expenses, including such as for teaming, blacksmithing, powder, and fuse, etc.; finally, a column showing the total cost of the extension, with another showing the estimated cost, for purposes of comparison.

As before stated, we have four thousand service-pipes in use. A petitioner for service-pipe is required to sign an application therefor, in which he agrees to pay such portion of the cost as we may assess upon him, and to take the water as soon as the pipe is laid. He is also required to deposit the estimated cost of that portion of the pipe upon his own premises, the city assuming the cost of the work in the street. The petitioner may elect the material for the pipe within his grounds, although the department strongly favors and recommends the use of lead.

The application being signed and the deposit given, an order is issued to the superintendent to put in the pipe, and notice is also sent to the engineer, who locates and plots the service, thereby incidentally furnishing a check upon the measurements returned by the foreman. As in the case of work on main pipe, a memorandum of stock used and labor performed is kept and returned to the registrar, by whom it is recorded in a service-register, arranged and ruled to take in the following-named data: Number of service; name of taker; street; ward; date laid; size of main tapped; size of service material; size and cost of corporation cock: cost of lead connection; distance from main to S.W. cock; S.W. cock to street line; street line to building; total length; cost per foot;

total cost of pipe; size and cost of S.W. cock; kind and cost of cover; cost of labor; cost of sundries; total cost to city; distance from street line to house; additional distance on premises; total length on premises; price per foot; cost of pipe to water-taker; charge for sundries; total cost of service to taker; date of adjustment of bill for service; and the date of turning on water.

Under a provision of our water ordinance the water board is required to attach meters to all services supplying other fixtures than faucets, also to fixtures supplying only faucets when more than three faucets are used; the board must also furnish meters to all water-takers desiring to use them, regardless of the fixtures supplied; the meters are furnished, maintained, and renewed at the expense of the city, except where they are injured through the negligence of a water-taker or by frost. The city charges a rental for their use, — the charge for the ordinary house-size meter being $2 per annum.

On receipt of meters from the manufacturer, they are carefully tested on $\frac{1}{4}''$ and $\frac{1}{2}''$ streams under a pressure of about 85 pounds; the results of these tests are entered in a "Record of Meter Tests," ruled to the following headings: Name of meter; pattern; size; number; length of test in minutes; size of orifice; number of feet run; weight of water in pounds; per cent. registered; and date of test. Upon being placed in service, a report is made and recorded as follows: Number of service; name of taker; number of meter; size; kind of fittings; cost of fittings; cost of setting; total cost.

OPERATION AND MAINTENANCE RECORDS.

The water having been conducted from the filter basin through the reservoir, distributing mains, and service-pipes, to the premises of the water-taker, upon application therefor and the adjustment of the bill for service, the pre-payment of that for water, and the setting of a meter, if one is required, an order is given for the turning on of the water to his house; such orders are upon written forms, and are returned duly indorsed by the person doing the work, with a statement of the fixtures in use. We are now ready to open an account with the water-taker, which we do in a book prepared especially for the purpose and known as our "Water Ledger;" he is there given the number assigned his service-pipe when laid. Our water ledgers are ruled for three accounts on a page, with a space for five years for each account. Over the headings are placed the service number; name of owner; name of tenant; street; ward; and description of premises. The headings are as follows: Charge for service-pipe; charge for building water; dates between which payment for water is made; number of faucets; cubic feet indicated by meter; gallons; rate per thousand gallons; amount due; date from which advance charge has been made; amount of advance charge; excess over advance; charge for sundries; abatement; amount paid; date of payment; amount and date of payment of meter rent; amount and date of payment of summons; date of turn off; date of turn on; date of sealing fixtures; date of payment of charges for turning off or on; sealing or unsealing; amount and date of payment of rebates. This form of ledger, which, it will be noticed, is applicable alike to metered and rated services, was devised to obviate the necessity of keeping separate ledgers for each class of water-takers; in it is provided appropriate and conveniently arranged space for

recording every description of charge, with its date of payment, that we are ever called upon to make against a water-taker. The accounts are arranged in these ledgers in the regular order of their service numbers; but they can be readily referred to when the number is unknown, by means of a card index, if the name of either the owner or tenant can be given.

The water bill for the fractional part of the year being paid, and the water turned on, no charge is necessitated against the taker until the end of the year, unless for some reason he has his water turned off, adds to his fixtures, or has his service or meter repaired.

Although the city owns and maintains all meters set since 1887, as has been previously stated, there were, when the ordinance providing for such arrangement went into effect, about one thousand meters which had been previously set by consumers and owned and maintained by them; to these the new arrangement does not apply.

No change in water fixtures can be made without the written permit of the board, and when application therefor is received, a record is made of the proposed change, and also of the report of the inspection of the premises which follows.

Repairs to services or meters may be the result of either a complaint from the taker of insufficient service or of a visit by the inspector to the premises.

A regular inspection of fixtures is made once a year, and a record taken of the name of owner of premises, name of tenant, street, ward, number of families, number of persons, and the number and condition of fixtures.

Regular inspections of meters are made four times a year; other inspections of certain meters are made from time to time, when deemed necessary.

Our water year begins March 1, and all meter accounts are adjusted twice a year; a minimum charge of $10 is collected from each taker on March 1 and on September 1. If at that time any taker has used more than this amount will pay for, he is billed for the excess; this explanation is made for a proper understanding of our meter inspection book, which is ruled with the following headings: Service number; name of owner; name of tenant; kind of meter; number of meter; size of meter; reading March 1; reading in March, April, May, June, July, August; quantity of water in feet and gallons; value; reading in September, October, November, December, January, February; quantity of water in feet and gallons; amount.

Our city is divided into seven wards, and a separate book is provided for each ward, in order that the record of the inspections of either, when completed, may be immediately returned to the office, and the posting to the ledgers be thereby facilitated.

The inspection of fixtures and meters is made by our inspector, who also has charge of our meter department; by the rules of the board he is required to have charge of testing, setting, and repairing meters, and to keep a careful record of the dates and results of all tests made, and of the condition of meters removed for repairs, both before and after repairs are made, with the date of removal and resetting. He is also required to keep a careful record of the cost of setting, repairing, inspecting, and removing all meters from their date of setting, with the annual and aggregate expense of maintenance, computed both per meter and per one hundred thousand feet of water registered.

Mention has already been made of the form of books used in recording the results of testing the meters, and also that containing a record of their setting; that adopted to meet the remaining requirements of the rules of the board is provided with headings as follows: Service number; name of taker; street; ward; number of meter; size of meter; date of setting; cubic feet registered to date; water pressure in pounds; then columns for description and cost of repairs by years. Meters of different makes are recorded by themselves.

RECORD OF RECEIPTS AND EXPENDITURES.

Collections for our department are made by the city collector through bills issued by the registrar. The statement before made, that where over three faucets are used meters are set and consumers charged meter rates, must be amended by excepting certain supplies furnished the city. But the city is only excepted from the rule in the matter of charges for hydrants and street-sprinkling; for the former it pays us $20 for each hydrant set, and for the latter the regular rate for measured water, its bills therefor being based upon returns made to us by the contractors for sprinkling, of the number of loads they have distributed upon the streets. As the capacity of their carts is known, the quantity of water can be thus obtained with sufficient exactness, and the necessity is obviated of setting and maintaining upon the number of stand-pipes we have the large number of meters that would be required.

Based upon the February inspection of meters and fixtures that have previously been referred to, the annual water-bills are made out by the registrar and given to the collector on the first of March. For convenience in handling we use a different-colored bill for each class of charge; the bills are all of uniform size, with coupon to be detached by the collector upon payment. When the bills have been made out, a memorandum of them is made in a book ruled so as to provide for a record of service number, name of owner, street, ward, description of bill, amount of bill, abatement, and amount and date paid. This book is given to the collector, and its footing shows him the amount he is expected to collect. Abatements of the bills are made only on certificate from the registrar to the collector, and the amounts and reasons for making same are duly recorded and reported to the water board. After each day's collection the collector transmits to the registrar the coupons retained by him, which are entered by the registrar in a book known as the cash-book, from which they are posted to the ledger. Our cash-book is ruled to provide for the entry of service number; name of taker, with a separate column for every description of charge, for this purpose there being 21 columns provided; a column showing the total amount paid, with date of collection; bills for fractional supplies and for services and sundry charges are made out, recorded, collected, and payment posted in like manner.

The book-keeper of a private business has a distinct advantage over one in public service, inasmuch as he is but little liable to the annoyance of a change in the personnel of his employer; his superior either instructs him to prepare his books after a certain form, or authorizes him to open them after his own ideas; this being done, the employer, from his personal and financial interest in his business, naturally familiarizes himself with the system adopted, and thereafter to give satisfaction the employee has only to keep his books closely to date.

A public official, however, must go further than this. From the frequent changes that occur in the different boards and committees by whom his work is inspected, it is not only necessary for his books to be closely posted up, but also that they should be kept to show operations in minute detail and in a manner to be readily understood by any one, whether or not he possesses a knowledge of book-keeping.

This is especially true in the matter of the expenditures of a department. Not to speak disrespectfully of our superior officers, we all know that far too often the more important consideration of the manner of doing a piece of work is sacrificed to the consideration of its expense, and that, in general, the capacity of the public for criticism — never by any means small — finds full scope for action in attacking an administration through its expenditures, often when they have been made with the utmost conservatism.

The expenditure of the department at Newton to the sinking-fund for the payment, when due, of the water debt, and that for the payment of the interest on water bonds, is provided for by the city council upon recommendation of its finance committee; all other expenditures, with the exception of those for salaries, before referred to, are controlled by the water board. An appropriation is annually made by the city council for maintenance of the department; one for an account known as the service and meter account, and one for an account called the rebate account. To the first is charged all that portion of the expense of maintaining and operating the works which the city must assume; to the second all expense of new work, or of repairs to old work, which is chargeable to the water-taker; and to the third all expenditures made in refunding to water-takers any portion of the rates they may have paid us.

Expense incurred by extensions, and all new work not chargeable to the water-taker, is charged to an account known as the construction account, for which no annual appropriation is made, but for which money is provided by the city council from time to time as the need therefor occurs, upon the recommendation of the water board, by a further issue of water bonds.

Under the rules of the department no expenditure whatever can be incurred without authority from the board, who hold weekly meetings, at which requests for permission to make expenditures which meet their approval are duly granted.

The pay-rolls of the department are settled weekly, but all bills are paid once a month. The bills of the department, after receiving the approval of the board, are entered by the registrar in a book known as the "bill-book."

In this book the bills are first entered in detail, and then charged to an appropriate heading under an account called the expenditure account; to some division or divisions under this account the total of every bill must be charged, and there may be as many divisions, which are all numbered, as may be required. At the present time we use twenty-five divisions, a few of which, noted by way of illustrations, are as follows: (1) Stock; (2) labor; (3) registrar's salary; (4) superintendent's salary; (5) teaming; (6) travel; (7) small supplies; (8) inspection; (9) miscellaneous expenses. After being entered under the expenditure account, the amount of the bill is carried to one or more, as may be, of the four remaining divisions of the page provided respectively for the maintenance, service and meter, construction, and rebate accounts. Each of these accounts may be

subdivided, like the expenditure account, as much as needed; some of the divisions used by us are, for the maintenance account, (101) water board; (102) registrar's office; (103) superintendent's office; (104) reservoir; (105) mains. For the service and meter account, (201) new service; (202) maintenance of service; (203) maintenance of meters. For the construction account, (301) new mains; (302) new hydrants; (303) new services. For the rebate account, (401) water rebate; (402) meter rebates.

As before stated, the full amount of every bill must appear in the expenditure column, and must also appear as a whole in either of the other four columns, or be divided among them as may be proper. For example: a certain pay-roll amounting to $432.59, as kept by us, would be charged under the expenditure account to (2) labor, $421.05; and (10) pumping-station salaries, $11.54, — which two charges would make the total of the roll; it would then be charged under the maintenance account to (111) standpipe, $3.50; (114) pumping-station, $11.54; (118) water troughs, $3.55; under the service and meter account it would be charged to (201) new services, $14.95; (203) maintenance service, $3.64; (204) maintenance meters, $8.00. Under the construction accounts it would appear thus: (301) new mains, $324.80; (303) new services, $47.23; (314) new meters, $15.38.

For another example let us take that of a bill for hydrants amounting to $100; after being copied in detail it will appear under the expenditure account, charged to (1) stock, $100; and again, under the construction account, charged to (302) new hydrants, $100.

It will be observed that the footing of the expenditure account must agree with the total of the bills entered, with which also must correspond the aggregate footings of the maintenance, service and meter, construction, and rebate accounts.

The especial advantage of this form of bill-book lies in the fact that it shows at a glance not only the amount of all expenditures, but the purpose for which they have been made, and the particular part of the work to which they have been charged.

Besides the bill-book are kept separate books for all the accounts above mentioned, appropriately ruled for their various sub-accounts, into which are posted monthly from the bill-book the required entries; there are also kept, besides these books, a journal and ledger, which, being of ordinary form, need no especial mention.

And now, gentlemen, having given you some idea of water-works records as kept by us, and thanking you for the patient attention you have given me, I resign the subject into your hands. If anything I have said shall prove of benefit to you, as your friendly criticisms will surely be to me, I shall feel amply repaid for the time spent on the matter. But I hope, nevertheless, that the subject will not be allowed to rest here. I do not think the importance of properly keeping the record of daily work in a profession like ours can possibly be overestimated. Particularly is it of importance to those of us having charge of a public system. If it is essential — and we all know that it is — for every private business of whatever nature, or however small, to be intelligently systematized, and to have its daily operations carefully recorded, of how much greater moment is it for us who labor for the public, and who are constantly under the supervision of the people's eye,

always critical, often unfairly so, — of how much greater moment is it for us, I repeat, to endeavor not only to accomplish all we undertake, be it work in-doors or out-of-doors, above ground or deep down in the earth, in the best possible manner, but also to so record our doings, that why a thing was done, how it was done, when it was done, and the expense of its doing, may at any time be ascertained, and readily ascertained, by any one having the right, who desires to know. We should not forget that though the works we build and manage may endure for all time, that we ourselves are here but for a moment; therefore, let us each so care for his charge as to make it possible for those who follow us to say, "He was a good public servant," realizing that by our records alone shall we be remembered.

THE ANALYSIS OF WATER, — CHEMICAL, MICROSCOPICAL, AND BACTERIOLOGICAL.[1]

BY

THOMAS M. DROWN, M.D., Professor of Analytical Chemistry in the Massachusetts Institute of Technology, Boston.

It would surprise most persons, I think, if they should look closely at a sample of pond or river water in a clean, white glass vessel. Water which we ordinarily think clear and colorless is then often seen to contain a good many floating particles, some pollen-like in appearance, others looking like shreds or fibres, organic *débris* of various kinds, and it may be, too, little white jumping water-fleas. After the water has stood quietly for several hours, some of these particles will sink to the bottom of the vessel and form a sediment.

Under the microscope many of the small particles which appear to the naked eye as mere points, or fine lines, are seen to be living vegetable and animal organisms, the variety of which is often very great and the number enormous.

Natural waters also contain much that cannot be seen with the naked eye or with the microscope, — that is to say, substances in solution, including organic matter, mineral matter, and gases, which can only be recognized by chemical means. Then there are the minute organisms known as bacteria, too small to be recognized except under the very highest power of the microscope, for the investigation of which a special method of bacterial culture is employed.

We shall be aided in the study of the complex composition of natural waters if we first consider how this infinite variety of forms and substances get into the waters. If we go back to the source of all waters — the rain — we find that, distilled water though it is, it is far from pure. It contains in solution the oxygen, nitrogen, and the carbonic acid of the air, and any other gases that may be present, as the sulphurous vapors from the smoke of cities, and also the dust and dirt which may be floating in the air.

[1] A lecture delivered before the Lowell Institute, Boston, Dec. 5, 1889.

As soon as this water touches the ground it starts at once for the sea. Let us imagine that it first falls on steep mountain slopes, far from the dust and smoke of cities, where the rocky bed and the rapid descent afford but little opportunity for the water to take up any foreign matters. These rapid mountain streams are justly associated in our minds with the idea of high purity. When the stream reaches more nearly level ground its progress is slower, and there is time for the water to dissolve from the ground any soluble matters which may be present. If the water flows through marshy lands it will acquire a yellowish-brown tint from vegetable coloring matters. All soils, too, give up to water in soluble form more or less mineral matter, particularly those of a calcareous nature. If the stream is sufficiently large and rapid, some of the earthy matters of its banks and bed may be carried along in suspension, — matters which settle to the bottom when the water is at rest. Thus in still bodies of water, which occur in the course of a stream, — the lakes and ponds, — we find the water generally free from suspended earthy matters; but it is in these bodies of still water that we find the greatest number of living organisms suspended, — the microscopic animal and vegetable forms.

This stream, with its ponds and lakes, which we have pictured, is, thus far, *normal*, a term which I would apply to natural surface-waters which have received nothing in any way connected with the life of man. Normal waters differ widely among themselves, according to the regions through which they flow. Some of them are but little removed from complete purity; some of them are far removed from it; but they are free from the waste products of human life and industry. The distinction is a useful one. All normal waters are not necessarily good waters to drink, but they can never cause those specific troubles which have their origin in the wastes of human life.

Following still further the onward-flowing stream, we find it coming within the sphere of man's activity, as, for instance, where it flows through land devoted to tillage and pasture, where the organic matter in the soil is largely of animal origin, from the fertilizers used and from the excreta of cattle. In farming regions the proportion of refuse from cattle is greater, as well as more widely disseminated, than that from man. When the stream passes through cities it receives the abundant and varied waste of human life, included under the name "sewage;" and it may be that the much-abused stream may be still made to bear the waste of factories which pour their often foul-looking and ill-smelling refuse into it. The water which left the sea pure and empty-handed, returns to it laden with the spoils of the land, the waste of the rocks and the soil, and the waste of life.

The elementary conceptions with regard to a water analysis are: —

1st. That we may have substances in water both dissolved in it and floating or suspended in it.

2d. That we may have animal, vegetable, and mineral substances in water, and all of them may be in solution, or all of them may be simply in mechanical suspension.

3d. That this animal and vegetable matter may be living and thriving in water, or it may be dead; and, further, that the non-living matter may be permanent, that is, with little or no tendency to decay, or it may be readily putrescible.

We can put the subject in another way; namely, we want to learn from an analysis not only what is in the water, but what is going on. Mineral matter, whether suspended as clay or dissolved as salt, suffers no change on standing, but animal and vegetable substances are susceptible both of growth and decay. From a sanitary stand-point it makes a great deal of difference, as we shall see, whether a water containing organic matter is permanent or undergoing change.

Before discussing the composition of water from a strictly sanitary stand-point I wish to call your attention to the mineral ingredients of natural waters which determine its value for many domestic uses. The most common mineral substance found in water is lime, any considerable amount of which makes the water hard; that is, it curdles soap, and no lather can be made with the water until all of the lime present has first combined with soap, making a curdy precipitate. The other mineral bases commonly found in waters are the alkalies, potash, and soda, and magnesia, also alumina, and oxide of iron. In combination with these bases are silica, sulphuric acid, carbonic acid, and chlorine.

The classification of waters, on the basis of mineral matter, may be made, first, as regards the amount of the mineral contents, and second, as regards their character. Thus, we distinguish between mineral waters and drinking waters, though it is not easy to say just at what point water ceases to be a potable water and becomes a mineral water. The popular distinction is as good as any; namely, that the mineral waters have enough mineral matter in them to give a taste to the water, and potable waters do not. The taste of a water is, however, a matter on which there is wide difference of opinion. When it is said that a water is good-tasting, some would mean, simply, that it was not ill-tasting, while others would mean that the taste was distinctly agreeable. Decided preferences for the water of a particular well or spring, as having an especially good taste, or as being especially refreshing, are very common. This is often merely a matter of temperature of the water, and not of taste. Taste is communicated to waters by the soluble salts and soluble gases. Distilled water is said to be flat and insipid, because it has lost its gases; more likely, because it has lost its salts. Pure carbonated water — that is, distilled water containing an excess of carbonic acid in solution — is sharp and pungent, but has none of the savor due to mineral matters. All the artificial carbonated table waters have a little salt or alkaline carbonates added to take off the flatness that pure carbonated waters have. It is not uncommon on shipboard, where distilled water is used for drinking, to add a small amount of alkaline salts to make the water more palatable.

To return from this digression, we distinguish, as I have said, mineral waters from drinking waters by the amount of salts in solution. But another distinction, and a very important one, entirely independent of the amount of salts present, is between saline waters and alkaline waters. The former, the saline waters, are in general like sea-water, though, of course, much more dilute. The mineral matter is mainly chloride of sodium — common salt — with variable proportions of lime and magnesia. The latter, the alkaline, contain mainly carbonate of soda, with variable proportions of carbonate of lime and magnesia, and generally much carbonic acid. The first class are represented by the bitter saline of St. Catherine's, Ontario, and the second class by the alkaline waters of Vichy and Carlsbad. Between these extreme types there are intermediate degrees, and we have natural mineral waters, like those of Saratoga, which are both saline and alkaline.

Surface waters — streams and lakes — contain, as a rule, much less mineral matter than ground waters, simply because they have less opportunity to dissolve them. Many surface waters in this vicinity contain only about 1 to 5 parts per 100,000 of mineral matter, or 0.5 to 3 grains per gallon. In limestone regions the surface waters are higher in mineral matter by reason of the ready solubility of lime in water containing carbonic acid. Saline lakes, like the Great Salt Lake and the Dead Sea, are abnormal, the accumulation of saline matter in them being due to the fact that they have no outlet, and that the evaporation from the surface is equal to or exceeds the water flowing into the lake.

A ground water contains mineral matter in character and amount dependent on the kind of rocks with which it has associated. The decay of the rocks, by the infiltration of atmospheric water, is a slow process, but one always in progress. By this means alkalies, lime, and magnesia are dissolved as carbonates together with silica, leaving a residue of insoluble clay. Waters which drain regions of crystalline rocks contain in solution carbonates of potash and soda, and relatively much silica. Such waters, filtering through soil, are deprived of their silica and potash, which enrich the soil, and lime and magnesia go into solution as bi-carbonates.

When carbonated waters act at great depths, under high pressure and at a high temperature, as, for instance, in the Yellowstone region, the decomposing effect on the rocks is very much enhanced, and springs of high mineral contents result, often containing much silica in solution.

An analysis made to determine whether a water is wholesome or not is made in a different way, and from a different point of view, from an analysis made to determine the character of its mineral contents. In both cases the analysis reveals to some degree the history of the water, — where it has been, and in what company; but the sanitary analysis concerns itself mainly in knowing what is the present condition and past history of the water as regards animal and vegetable life. To say that a sanitary analysis is one which is chiefly concerned in the *life history* of a water expresses well its object and scope.

A prevalent notion regarding the methods employed to determine whether or not a water is good to drink is that a chemist makes his tests for the unwholesome substances, just as he would make a test for arsenic or lead in the water. It may, perhaps, be a statement that will surprise many of my hearers when I say that, apart from vegetable or mineral poisons accidentally present in water, a chemist has never yet found any substance in water which he could say with certainty was of itself the cause of disease.

A thorough sanitary analysis of water is three-sided, —

First. The solid matter in the water is separated by filtration, transferred to the slide of a microscope, and examined. This tells what animal and vegetable forms are present. By taking measured amounts of water and counting these forms a quantitative determination of them may be made.

Second. A very small amount of water is tested, by a method to be presently described, to determine the number of bacteria present.

Third. The chemical analysis is concerned in discovering the amount and kind of mineral and organic matter in the water. If organic matter is present, its character and condition must be investigated to see whether it is capable of decomposition, and whether it is in the process of decomposition. If no organic

matter is present, then the mineral matter must be examined to see if any of it had its origin in organic matter. From the data thus collected — the microscopic life, the bacteria, the amount and condition of the organic matter — we draw our conclusions as to the sanitary quality of the water.

It is a common notion that a drop of water seen under the microscope will reveal such a frightful collection of animal life that one will have a well-grounded distrust of water ever afterwards. Many of us can recall with what fascination and horror we first saw the fearful-looking monsters projected on a screen from a magic-lantern. But if the microscopist should go about his work in this way, looking at single drops of water, it might be very long before he would be rewarded by the sight of anything at all. The method he uses is to filter a considerable quantity of water through cloth, or, better, fine sand. This intercepts the organisms, which can then be transferred to a slide and examined.

A good ground water, free from organic matter, should contain no life of any kind. It may contain plant food; but green plants cannot grow in absence of light, and fungus growths, which do not require light, need organic matter. If we find life (vegetable or animal) in well-water it is because the conditions of growth are present, and this is abnormal and suspicious.

In surface waters the conditions are different. Ponds often swarm with life, and the water is not necessarily the worse for it. The vegetable forms commonly met with in water comprise the algæ, among which we distinguish the green, the blue-green, and the brown-green, or the diatoms, which live, like other green plants, on mineral food, and the fungi, which have no chlorophyl, and cannot live entirely on inorganic matter.

The green algæ, common forms of which are Spirogyra, Volvox, Draparnaldia; and the diatoms, among which may be mentioned Asterionella, Melosira, Synedra, Pinnularia, — live abundantly in waters of good ponds and rivers. They may be sometimes themselves the cause of unpleasant tastes and odors, but their presence does not indicate anything objectionable in the water in which they live. The blue-green algæ, which also live in good waters, — at least in waters which are entirely free from human wastes of any kind, — attain, at times, an enormous development in ponds and reservoirs, and become a nuisance by reason of the rapid decay of a jelly-like substance which they secrete. Cœlosphærium, Anabæna, Clathrocystis, Oscillaria, and Nostocs are varieties of these blue-green algæ.

The most frequent animal forms may be grouped under the Rhizopods, the Infusoria, the Worms, and the Entomostraca (or water-fleas). A good surface water may contain any or all of these animalcules in small numbers, and their presence in such waters may actually contribute to its excellence, provided they be few. The presence of large numbers, however, justifies suspicion, since it indicates decomposable organic matter present in the form of food, and may also lead to bad tastes and odors as the outcome of their vital activity. Some infusoria, such as Euglena, and some worms, such as Anguillula, and certain rotifera, seem to indicate considerable contamination, since they seldom occur except in polluted waters, where, it is to be inferred, they find appropriate food, *i.e.*, abundant and possibly solid and easily decomposed organic matter.

The fungi are to be interpreted very differently from the animal forms which, in their lack of chlorophyl, they resemble. Like the animals, they are dependent

upon foods more highly organized than merely mineral matters; but, unlike the animals, they do not absolutely require what is commonly known as "organic" matter. They are able to live upon the least decomposable kinds of organic matter, upon which no animals could survive. Hence their presence is not necessarily suspicious.

Some of the fungi absolutely require certain mineral matters, and it seems not to matter so much with them as to the rest of their food. The fungus, Ceggiatoa, called also the "sewage fungus," is known to thrive in sewage-polluted waters, and hence its presence in a water has been thought to indicate the presence of decomposing animal matters. But the substance that the Ceggiatoa absolutely needs for its life is sulphur, and that seems to be the reason why it grows so luxuriantly in sewage waters, which always contain more or less sulphuretted hydrogen. It is said that this fungus grows equally well in natural sulphuretted waters, provided there is some kind of organic matter present.

There is another interesting fungus, found both in surface and ground waters, called Crenothrix. For its growth iron is necessary. A very remarkable case of rapid development of this fungus occurred in the Berlin water supply a few years ago. Water drawn from wells on the borders of Tegel lake, perfectly clear and colorless as it came from the ground, became, on exposure to the air, turbid, and deposited a rusty-brown sediment consisting of this Crenothrix and oxide of iron. The iron was in the water in the form of protoxide, in very small amount; but there could not be any oxidation in the ground, and consequently no growth of the Crenothrix, because of the absence of oxygen. On the exposure to the air, however, all the conditions were present for its rapid growth. No means could be thought of to stop the trouble, and the supply from this source had, therefore, to be abandoned. The same trouble exists at times, during warm weather, at the Wayland water works in this State, where water is drawn from filters on the bank of a reservoir.

The total number of organisms in any sample of surface water is often very large — 25,000 to a tumblerful is not an unusual number for Cochituate. In the Newton water there are no organisms as it comes from the ground, but on exposure to the air the growth of diatoms is often so enormous that 1,000,000 to a tumbler would not be an exaggeration.

The bacteria belong to the lowest form of life; a simple cell, with wall and contents, capable of self-nourishment and reproduction. Until within a few years their presence was unknown and unsuspected, so minute are they, and yet their importance in the economy of nature is such that higher life would come to an end if their activities were to cease. It is unfortunate that these ever-present, humble, useful organisms should be associated in our minds mainly with evil purpose and effect. True, there are malignant bacteria, to which we cannot assign any beneficent rôle in nature; but so there are poisonous fruits.

The bacteria, or germs, as they are also called, have many shapes: the ball or egg-like forms include the genera micrococcus and streptococcus; the rod-like forms, the genus bacillus; and spiral forms, the genus spirillum. A special form of bacteria we have all become familiar with in name, — the cholera germ, called by Koch the comma bacillus.

The function of the green plants is to make organic material out of the inorganic. Trees, grass, and vegetables live entirely on the carbonic acid of the air

and the water and mineral matters in the soil. Animals cannot do this, but require either vegetable or animal food. In utilizing this food the animals do not reconvert it all into mineral matter again. The nitrogen in the proteid, or albuminoid matter which they consume, is not excreted in the oxidized form of nitrates, but as urea, a compound related to ammonia. Then the bacteria step in, find food for their support in the waste which has no more value for animal life, and complete its conversion into mineral matter that it may again serve as food for plants.

This is only one aspect of bacterial life, but it is the one most closely related to the subject we have in hand. Bacteria are also capable of beginning with the albuminoid matter and carrying it through all the changes which result in its complete oxidation. It matters not to them whether their food is, say, the albumen itself, or what man discards after having used the albumen for his food; the bacteria will accomplish the same end in both cases, namely, the complete mineralization of the organic matter. These busy, active bodies have this function: to take organic matter or organic waste, break it up, rearrange its atoms, and deliver back to the earth again the mineral matter which the plants have taken from it.

This sounds almost like a tale from wonderland, and yet these changes are very familiar to us all. We call them by various names, — oxidation, decomposition, decay, putrefaction. It was formerly thought to be purely a chemical process. By exclusion of the air, as in the various processes of preserving foods by canning, decay could be averted; but in the presence of air the processes of oxidation were supposed to be necessary and inevitable. To-day we know that there will be no change in organic matter, even in air, if these micro-organisms are excluded or rendered inactive.

Just a word with reference to the method used to determine the number of the bacteria in water. It is based on the principle that by stimulating their growth, and making them increase enormously within a small space, in which they cannot move, the aggregations of the newly developed bacteria will be so large that they can be seen by the naked eye. This ingenious suggestion was carried out by the famous bacteriologist, Koch, in this way: A small quantity, usually one cubic centimeter, of the water (that is, about one-fifth of a teaspoonful) is mixed thoroughly with, say, ten times its amount of a sterilized solution of gelatine, which contains extract of beef, peptone, etc., to make it highly nutrient, and the mixture is poured, while warm, upon a glass plate, so that it forms a thin layer when solidified. This is set aside for a few days in a warm room under a cover and protected from the germs in the air. If bacteria are present in the water they will grow with great rapidity under these conditions, each bacterium forming a colony, as it is termed, of thousands or millions of bacteria. Then we can see and count them. It is assumed that each colony arose from a single bacterium in the water; hence by counting the number of colonies on a plate we arrive at a determination of the number of bacteria in the cubic centimeter of water used.

The numbers of bacteria, as determined in this way in natural waters, vary greatly. A water taken directly from the ground, at a depth of six feet or more, should contain none. In good pond waters may be found anywhere from a few score to a few hundred. In polluted streams they may run up well into the

thousands or hundred thousands, and in sewage they can be sometimes counted in the millions.

The most obvious inference to be drawn from the presence of living bacteria in water is the same as that drawn from the presence of any kind of life; namely, that there is food for them there, and the greater the number of them the more abundant the food. This is the simplest expression of their silent testimony to the quality of the water. At the present moment we cannot stop to speak of the many conditions which may modify this testimony. Let it suffice for our present purpose that bacteria in water mean decay of organic matter, and that their number bears some relation to the amount and rate of decay going on. At a subsequent time we shall return to them and study their diverse activities somewhat more closely.

Organic matter is composed of carbon, hydrogen, oxygen, and nitrogen; at least, for our purpose it will suffice if we so consider it. It is only the nitrogenous organic matters which undergo those kinds of changes which we include under putrefaction, and which we regard of importance from a sanitary stand-point. Familiar examples are milk and meat, which when exposed to the air become offensive, but starch and sugar (which contain no nitrogen) do not.

A typical nitrogenous substance we have in albumen, which is a product of both animal and vegetable life. It contains about sixteen per cent. of nitrogen. Animal tissues and fluids are largely composed of albuminous or proteid substances, as they are called; vegetables contain them only in small amount. Muscle, which forms a large part of the higher animals, contains about fourteen per cent. of nitrogen. The cereals contain about two per cent.

The nitrogen, which we find on analysis from undecomposed animal and vegetable matter, say fresh albumen, we call "organic nitrogen," by which we mean that the nitrogen is still in its original organic combination before change or decay has set in.

The first stage of decay is the oxidation of the carbon, either from the oxygen of the substance itself or oxygen from without, and this leaves the nitrogen and hydrogen, which unite to form ammonia. The determination of carbonic acid, as an evidence of beginning decomposition in water, is of but little value, since carbonic acid is present in the atmosphere, and may come from many sources; but the determination of the ammonia thus formed is of the greatest significance. Leaving out of consideration that present in rain-water, we may say that ammonia in water is distinctly characteristic of the first stage of the decomposition of organic matter.

As decomposition progresses the ammonia itself is oxidized, — both of its elements, — the hydrogen to water, and the nitrogen first to nitrous acid, and lastly to nitric acid. The acids thus formed combine with some of the bases present, let us say potash, and we have neutral compounds formed which remain in solution in the water. The potash compound of nitric acid is common nitre or saltpetre. This process of nitrification which goes on in water on a very small scale is the same by which saltpetre is made on the large scale in nitre beds, where rapidly decomposing animal matters are mixed with bases, such as lime or potash, and exposed freely to the air.

The principal object of a sanitary chemical analysis of water is to determine the amount of nitrogen present in these four forms: organic nitrogen, ammonia,

nitrous acid, and nitric acid. The significance of these determinations is this: organic nitrogen represents the possibilities of putrefaction still remaining in the water, ammonia represents decay begun, nitrous acid (or the nitrites) represents decay still further advanced, and nitric acid (or the nitrates) represents the completion of those oxidizing processes which, taken together, we call decomposition or decay.

The nitrates are purely mineral substances, all traces of the organic origin of their nitrogen being lost, and they have no more significance in water analysis, *as such*, than if we had taken a pinch of nitre and added it to the water. I say as such, for you read in some books on sanitary matters of the "deadly nitrates" in water, when the fact is that the nitre in natural waters is in no wise different from the nitre we eat on corned beef. But the significance of the nitrates is this, they tell of a past history of a water which may be far from praiseworthy. High nitrates in water means that there was once much organic nitrogen and much decay going on in that water, and possibly some taint may hang around it still.

The organic nitrogen, representing organic matter which has not begun to decay, has generally been thought particularly objectionable in water because it carried with it the possibility of further decay with all its attendant dangers. But this view ignores the fact of the great dissimilarity of organic substances in this respect. Animal matters, as we all know, are, as a rule, much more readily putrescible than vegetable matters, and the products of their putrefaction are usually more offensive. Much of the vegetable matter, particularly that which gives a brown color to the water, is, in reality, very stable, and to class the organic nitrogen in a substance of this character with that contained in a substance like albumen in blood is a manifest absurdity.

To have but the one idea of nitrogenous organic matter in water, namely, that it is inherently capable of decomposition, and to make no distinction as to the likelihood of its decay, is so obviously an inadequate view of the subject, that no importance can be attached to opinions based merely on the presence of organic nitrogen.

It is a well-known fact that sea-captains going on long voyages have taken with them by preference dark, swampy waters, because they keep particularly well. These waters show on analysis high organic nitrogen, and would on most English standards be condemned as "polluted."

I have thus far used the term "organic nitrogen" as expressing precisely the idea which I wish to convey, but on the tables of analyses [1] before you, you will not find this expression, but in place of it another, which I have not hitherto mentioned, namely, "albuminoid ammonia." It is an unfortunate fact that our methods of determining organic nitrogen have been, until recently, very tedious and difficult, and not always reliable, so that chemists have resorted to another process, which gives only a part of the organic nitrogen in the form of ammonia. That is called albuminoid ammonia, because albumen, when subjected to this process, gives up its nitrogen as ammonia.

The process in question, invented by Wanklyn, Chapman, and Smith many years ago, is so easily and quickly performed, and gives results of such great

[1] The tables are not reproduced in this publication.

comparative value, that it has come into almost universal use, so that in the very large majority of water analyses made at the present day albuminoid ammonia takes the place of organic nitrogen. From a long series of experiments I have made, I think it safe to say that the albuminoid ammonia, as determined in most of the surface waters of this State, is about one-half of the total organic nitrogen in the water.

Beside the determination of the organic matter in the water, the determination of the amount of chlorine has the greatest significance, from the fact that the waste of human life in its various forms contains a large amount of salt — chloride of sodium. The finding in a water, therefore, of a large amount of salt, or what is the same thing, of chlorine, is strong evidence of the presence of drainage or sewage in the water. That this evidence should have any value, it is obvious that the amount of chlorine in the water in its natural condition must be known. No natural waters are without some chlorine, but the amount varies very widely. Streams and wells in the regions of salt deposits may contain a very large amount, and waters near the sea are also apt to be high in chlorine. To form any opinion of the character and history of a water from its chlorine contents, without knowing the *normal chlorine* of the water of the region, is clearly impossible.

The systematic examination of the waters of Massachusetts instituted by the State Board of Health has enabled us to establish the normal chlorine for all parts of the State. To do this it is necessary to know by actual inspection that a water, say a brook with a limited drainage area, receives no house drainage whatever. Repeated determinations of chlorine in the water extending over a year or more, in dry and wet seasons, will give an average of normal chlorine contents for this drainage area. This has been done for the whole State, with the practical and eminently useful result that we are able to tell with high probability when any stream is contaminated with drainage, and to just what extent. In general it has been found that for the surface waters of this State the amount of chlorine decreases as we go westward from the sea.

The instances in which this minute knowledge of the normal chlorine of the State has proved of value in detecting pollution in surface waters have been very numerous. I will mention one instance. In the samples regularly received from the water supply of a town in the western part of the State, the chlorine was found to be slightly, yet persistently, above the normal of the region, and, together with this, the ammonia was repeatedly higher in amount than was consistent with our notions of a good pond water. Inquiries as to the possibility of contamination elicited only the statement that the pond received no drainage of any kind, and that the drainage area was almost free from population. It looked very much as if the value of the normal chlorine determination was to be seriously impaired by reason of this unfortunate exception. But a visit to the locality revealed the fact that the pond supplying the water was a reservoir formed by damming a very small brook, a mere thread of a stream, and that in a field through which this brook ran, but a few rods before it widened out to form the reservoir, cows were grazing, and some were standing in the brook itself. So small was the size of the reservoir that the water which left this field in the morning might be supplied to the consumer before night. A sample of water from the same brook was then taken about half a mile or more above this field,

on land free from all pollution, and to our satisfaction it was found to have only the amount of chlorine which the region called for.

These normal chlorine determinations apply primarily to the surface waters of the State. The ground waters follow, in general, the same rule of increasing chlorine from west to east; but inasmuch as many of the rocks contain some chlorides, which can be leached out by the waters in long contact with them, the regularity of the increase cannot be so confidently relied upon, nor can we be so sure that the normal chlorine determined in one ground water will apply for any large radius around it.

Let me give an instance of the application of this idea of local normal chlorine to the detection of pollution of a well by drainage. A householder in a suburb of Boston having had several cases of sickness in his house, had the water of his well examined. It was found free from organic matter, but with very high mineral contents, including high chlorine and nitrates. Contamination of the water of the well by the drainage of the house was said to be impossible, such were the relative positions of well and cesspool. The evidences of local contamination, furnished by the chemical determination, were strong enough to make one doubt the testimony thought to be based on positive knowledge. The simplest way to decide the matter was to find, if possible, what was the normal chlorine in the ground water of this region. Fortunately there was another well in the same body of gravel on which the house was built at a slightly greater elevation; the water of this well was examined and found to contain only about one-tenth as much chlorine as the water of the suspected well. Digging revealed the fact that the house-drain to the cesspool passed near the well, and that this portion leaked, so that the ground around the well was thoroughly soaked with decomposing matter.

In the description of the general nature of the chemical analysis of water which I have just given I have had mainly in mind the analysis of surface waters containing life, animal or vegetable, with their possibilities of decay. The ground waters are very different in character. A good ground water, from spring or well, should be both colorless and clear, with no trace of turbidity and no trace of life. Of organic nitrogen, of ammonia, and of nitrites there should be none; but nitrates are generally present. As we shall see in a subsequent lecture, the most favorable conditions for the oxidation of organic matters are those which exist in porous soil, so that water containing nitrogen in any form becomes, when slowly percolating through soil, entirely purified; that is to say, the nitrogen is all converted into the mineral form of nitrates. When the water which we draw from the ground has never known other forms of nitrogen than that derived from the ammonia of the air, or the vegetable matter on the surface, then we find the nitrates very low; they may even be entirely absent; but when as surface water it has been contaminated with animal refuse, then we find the nitrates high. These two substances together in water — the nitrates, and the chlorine when above the normal — give evidence which is absolutely conclusive that the water in some part of its course has been in bad company. If we can be sure that the last traces of organic matter are destroyed, with all the intermediate products of decomposition, and that all the bacteria with which this organic matter was originally swarming are dead, then the presence of the chlorine and nitrates need not worry us. But can we ever be quite sure of this?

When the source of pollution is near, we may have a water free from organic matter to-day and full of it to-morrow, — a possibility which is more remote in proportion as the source of pollution is farther removed. There can be no rule given to cover all cases of this kind; each one must be the subject of special investigation as to source, nature, or distance of the organic matter. But one principle it is well always to bear in mind, it has been well expressed by Dr. Kedzie, of the Michigan State Board of Health: "In a drinking-water, what we demand is innocence, not repentance."

In the tables before you with the heading Sanitary Analysis you will notice many other determinations than the four forms of nitrogen and the chlorine to which I have referred. They are color, odor, turbidity, and sediment of the water, the total solids, loss on ignition, change on ignition, and the hardness. To this list I might have added others, as the oxygen dissolved, the oxygen required to oxidize the organic matter, and many others in ordinary use, which give valuable information as to the origin and condition of the water. A full description and discussion of these chemical determinations are clearly out of the question in the time we have to devote to the subject, and I have thought it more profitable to confine our attention mainly to this one side of the chemical study in water, namely, the detection of harmful pollution by means of the changes in nitrogenous matter. This, taken in connection with the evidence offered by the chlorine, will, if correctly interpreted, generally lead us in the right direction.

It will be of assistance in recognizing in an analysis the evidence of pollution of a water, if we take a nearer view of the character and composition of the typical polluting material, namely, sewage.

Sewage is the water supply of a city as it passes out. It is a very variable substance. It differs in composition in different cities, and in the same city it differs in character at different seasons of the year, and even at different times of the day. The greater the amount of water used *per capita* in a city, the more dilute the sewage will be; the sewage of a manufacturing city is of a different character from that of an exclusively residential city. Sewage flowing at night will naturally have less solid matters in it than that flowing by day; and if the rain-water, also, has access to the sewers, the sewage of wet weather is very much thinner than in dry weather.

But certain things characterize all sewage, and distinguish it from the water supply; namely, an increase of mineral matters, including salt, and an increase of nitrogenous matter, in the first stage of decomposition, that is to say, with high ammonia.

Sewage is not attractive in appearance, and our associations with it are far from pleasant, and yet the amount of decomposing matter in it is really very small. Suppose it contains one hundred parts of solid matter per one hundred thousand, a rather large amount, this means only one-tenth of one per cent., or fifty-eight grains to the gallon, a considerable part of which is mineral matter. Another way to put it is, that sewage is over ninety-nine per cent. water.

The condition of the nitrogen is significant and characteristic. It is mainly in the form of free ammonia, the albuminoid ammonia (or organic nitrogen) being always very much less. There is none of the nitrogen oxidized, and the sewage contains no free dissolved oxygen. All the oxygen that was originally in the water has been consumed in the oxidation of the carbon of the organic matter,

and it has not sufficed to oxidize any of the nitrogen. The organic part of sewage may thus be said to consist of nitrogenous matter in the act of decay, and that this decay has been temporarily arrested by the failure of the supply of oxygen. As soon as it gets more oxygen, by exposure to the air, or by flowing into water which is abundantly aerated, decomposition is resumed, for the bacteria of decomposition are all ready to begin operations again as soon as the necessary oxygen is available.

If now we look for evidence of sewage pollution of a water in its contents of nitrogen, we shall find it in the free ammonia, if the pollution is recent and near by; but if the pollution was more or less remote, and there has been opportunity for oxidation of the nitrogen, then we may expect the presence of nitrites and nitrates. The chlorine, and the mineral contents in general, will not change in character or amount, but the relative amounts may be much reduced by dilution.

From analyses of water, such as I have described, what have we learned? First, by means of the microscope, the kind of life existing in the water, from which we draw conclusions as to the kind and quality of the food which supports this life. Second, by means of the gelatine plate cultures, the number of the bacteria in the water, from which we draw conclusions as to the amount and kind of decay going on. Third, the chemical examination reveals to us directly the amount of organic matter and the conditions in which it exists. These widely different methods are merely different points of view. It is one and the same thing throughout which engages our attention; namely, the life processes which are going on in the water, for decay is but the manifestation of another form of life.

If it is asked why our study is centred here, the answer is simply, that experience has taught us that it is the organic matter which is the cause or accompaniment of disease; it is in the decomposition of this organic matter, somewhere in the changes that it undergoes in the process of decay, that danger lurks. This is the chemical expression of the causation of disease. The biological expression takes another form; namely, that the bacteria which cause changes in the organic matter, cause also disease. The two expressions do not contradict each other, but go hand in hand. The specific action of the bacteria will be more fully discussed in the next hour, — let the chemical idea suffice for this, namely, that *the state of change is the state of danger.*

Table of Contents.

	Page
Register of Attendants at January Meeting	93, 94
Paper, "Some New Experiments and Practical Tables relating to Fire Streams," by John R. Freeman, Hydraulic Engineer	95–167
Discussion by Messrs. Tidd, Jones, Haskell, Shedd, Hawes, and Winslow	168–171